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Final Report of the Passive Radio-Frequency Identification (RFID) Project at the Fleet and Industrial Supply Center, Norfolk, Virginia, Ocean Terminal

(Version 8.0, 20 October 2004)

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Executive Summary

The Fleet and Industrial Supply Center (FISC), Norfolk, Ocean Terminal Division (OTD) Container Freight Station (CFS) has been a leader in the implementation of passive Radio Frequency Identification (RFID) in the Department of Defense (DoD) since November 2003, and a key player in DoD automatic identification technology (AIT) integration since the early 1990s. The small passive RFID quality control initiative that was started at FISC in November 2003 has since expanded into a complete RFID operational solution that became fully functional in May 2004. Since that time, FISC has abandoned their legacy handheld scanning processes in favor of the new EPC-enabled documentation procedures, which document shipments by scanning RFID tags passing through a portal. As a result, the Norfolk Ocean Terminal is now positioned to effectively utilize passive RFID tags affixed by suppliers and other DoD activities, in accordance with DoD RFID policy dated 30 July 2004. As DoD moves forward with its current RFID initiative and the further integration of other enabling technologies, the Norfolk Ocean Terminal will continue to be a testing ground, providing valuable lessons learned and experiences for the Navy and DoD.

The goal of the FISC Norfolk Ocean Terminal passive RFID pilot was to increase manifest accuracy and inventory accountability within the Ocean Terminal by mitigating the number of errors introduced into the process by manual and/or nominally automated procedures. In its final configuration, the process has also been found to increase speed and efficiency of the cargo checking process.

The Ocean Terminal now uses RFID tags to process all shipments except household goods, classified shipments processed by the division at a remote site, and outsized shipments processed in the outside storage area. During the receiving process, RFID tags are placed on each piece of the shipment and the corresponding Electronic Product Code (EPC) is linked with the appropriate Transportation Control Number (TCN) and piece number in the Ocean Terminal Management System (OTMS).

When loading for a specific container begins, the name of each Material Handler working to load that container is linked, in OTMS, to the container number, doorway, and port of debarkation (POD) of the container. Material Handlers then retrieve shipments from stow and present themselves, with the material, at the RFID Portal. Upon their arrival at the portal, they identify themselves to the portal operator, who calls up the appropriate container using the Material Handler's name. The Material Handler then indicates the number of shipments currently on the forklift, which is keyed into OTMS by the portal operator.

As the forklift passes through the RFID Portal with the shipments, the portal responds with a variety of audible and visual signals as to the progress of the RFID reading process. The checker operating the portal is presented with a detailed screen, showing the identification of each shipment detected during the read process, and indicating via a color-coding scheme, whether or not it is appropriate for the shipment to be loaded into

the container. The driver is then given visual and audible signals to either proceed to the container or wait for instructions from the portal operator.

OTMS collects all information associated with the scanned shipments and consolidates it into the proper container, updating both shipment and container records in the Worldwide Port System (WPS) as appropriate. Once container loading is complete, a hardcopy container consist is printed and affixed to the inside of the container door. For containers destined to the CENTCOM area of responsibility, the consist information is also written to a DoD Intransit Visibility (ITV) Active RFID tag which is fastened to the outside of the container.

In the legacy container loading process, one employee would be assigned to each container being loaded in a quality control/documentation role ("the checker"), and one-to-two others would operate forklifts ("the drivers"). The checker would scan and validate each shipment brought from stow to the container doorway by the drivers before those shipments were loaded into the container. The new process utilizes a single checker operating the RFID Portal, which simultaneously services all containers being loaded. Additional Material Handlers who would have been in a checking role under the old process are now free to be assigned as additional drivers in the loading process, or reallocated to other areas of the operation. This reallocation of manpower provides a significant improvement to the overall efficiency of the operation.

Passive RFID technology is not a panacea to the issues and challenges within the complex DoD Supply Chain. There are currently many technologies employed to facilitate process automation and provide timely, accurate, and useful supply and transportation data. Passive RFID is simply a recent addition to this list of capable technologies, providing real return and improvement to supply chain business processes. Integration of this new enabler will require extensive reviews and revisions to existing business processes. RFID cannot succeed if simply inserted into current barcoding operations.

The testing and pilot phases of this project received funding of $60K from the Ocean Terminal's FY03 funds, $15K from the Ocean Terminal's FY04 funds, and $180K in FY04 funds from the Navy AIT Steering Group. The funding was used to purchase hardware, portal equipment and contractor support used in the effort. A second phase of this project, not covered by this document, includes expansion of the RFID-enabled transactions of record to receiving operations. This second phase is funded with FISC Norfolk and Office of the Assistant Undersecretary of Defense for Supply Chain Integration funds.

Background

The FISC Norfolk Ocean Terminal operates a common-user Container Freight Station (CFS), which receives less-than-container-load (LCL) shipments from military depots, military shippers, and vendors from throughout the continental United States (CONUS). These shipments are consolidated by consignee and destination, and are loaded into International Standards Organization (ISO) 20 and 40-foot SEAVAN containers for transport via commercial sealift. The CFS processes approximately 50,000 export shipment units, annually, into approximately 3,000 SEAVAN containers. These shipment units range in size from single small envelopes to large multiple-pallet configurations. Each shipment, regardless of size, requires the same documentation and manifesting steps when received at the terminal and loaded into a SEAVAN container. Each piece of every shipment loaded into a SEAVAN container must be accounted for to ensure the manifest created for that SEAVAN reflects an accurate representation of the contents.

Concerned with inaccuracies in the on-hand inventory journal for the terminal, FISC Norfolk Ocean Terminal managers determined that an unacceptable number of shipments were being loaded into SEAVAN containers without being properly documented on the manifests. As these manifesting errors were having potential impact on the consignee's ability to utilize intransit visibility (ITV) data to properly plan for receiving and foreign country customs clearance, a solution to the problem needed to be found. One potential solution that presented itself was the use of passive radio frequency identification (RFID).

Legacy Process

In the legacy receiving process, receiving personnel utilize the Ocean Terminal Management System (OTMS) to perform transit shed receipts. OTMS acts as a middleware solution providing automatic identification technology (AIT) enhancements, interfaces with Defense Automated Addressing System Center (DAASC) and Navy Operational Logistics Support Center (NOLSC) applications, a customized graphical user interface (GUI), and live updates to the system of record, the Worldwide Port System (WPS). Within the OTMS receiving process, Advance Transportation Control and Movement Document (ATCMD) data submitted by shippers via WPS, when available, is combined with information obtained from linear or two-dimensional (2D) barcodes on Military Shipping Labels (MSL) and Material Release Orders (MRO), and information obtained from the Web Logistics Online Tracking System (WEB LOTS), to build a Transportation Control and Movement Document (TCMD) in WPS, and to populate a Level VI database in OTMS. OTMS also updates the status of the record in WPS to show receipt and the current location of the shipment. WPS, in turn, then updates the Global Transportation Network (GTN) with the same information.

Figure 1 *FISC Norfolk Internal Freight Tracking Labels before and after implementation of passive RFID*

As part of the receiving process, each piece in a shipment, as determined by the type of package code and piece count on the TCMD, is labeled with a FISC Norfolk Local Shipment Identification Label, which provides CFS warehouse personnel with additional information on staging, handling, and loading shipments – information that is either missing, inconsistently reported, or too inconspicuous on the shipping labels used to deliver the freight to the CFS *(see figure 1)*.

After receipt, shipments are staged in the CFS based on Port of Debarkation (POD), HAZMAT compatibility, and pilferability of the shipments.

Figure 2 *Legacy scanning of freight using a JANUS JR2020*

During SEAVAN loading (referred to as container stuffing), shipments are selected from the staging area based on their destination, consignee, age, compatibility, size and shape. As shipments are moved from the staging area to the SEAVAN, they are scanned with a JANUS JR2020 scanner (see figure 2). This scanner is linked to the OTMS system via a radio frequency (RF) communications link. The shipment is verified as valid for the POD to which the SEAVAN is being delivered, and if valid, is connected to the SEAVAN container as a content. This process requires that every shipment unit being loaded into the SEAVAN be scanned one at a time. In the case of a SEAVAN that will carry 100 small envelopes or small boxes, each envelope and box must be individually scanned. Because of the RF interaction on each of multiple input screens associated with each stuffing transaction, this process is time consuming. In addition, despite many management reviews, business process changes, and quality control initiatives, an unacceptable percentage of shipments continue to make it into SEAVAN containers without having been scanned. In these cases, the shipments arrive at destination without having been manifested. They also remain on the CFS on-hand journal as ghost shipments, making it impossible to manage container ordering and loading using that document.

Household goods (HHG), oversized/overweight shipments, and classified material each have unique processes, which differ from the methods used for general cargo. These cargos are handled in different locations or by different personnel.

Specifically designated personnel handle household goods in a separate section of the CFS building. Personal property is received with hardcopy documentation, which is annotated on the warehouse floor, and later updated into WPS by a Transportation Clerk. HHG shipments typically do not have a MSL, but have stenciled information, instead. HHG shipments are stuffed into SEAVANs using a JANUS JR-2020 scanner. Personal property and sustainment cargo are only co-mingled if there is insufficient cargo volume to fill an entire SEAVAN with one or the other.

Outsized and overweight shipments that require a crane for handling and/or cannot fit through a standard truck doorway are documented using annotated hardcopy TCMDs, which are later updated into WPS by a Transportation Clerk. These shipments are frequently of a shape or configuration that is inconsistent with a standard MSL. They are also subjected to the weather during transportation and storage, which plays havoc with paper shipping labels and barcodes. The outside storage area at the CFS is also outside radio range for the JANUS JR2020 scanners. Depending on the type of SEAVAN (flat rack, open top, etc.), the outsize/overweight shipments are loaded, and then the SEAVAN is moved to a doorway to be filled out with general cargo.

CFS personnel handle classified shipments at a remote location. Classified shipments are not loaded into SEAVANs at the CFS, but are added to the SEAVAN after all other freight has been loaded, and the SEAVAN has been moved to the Special Materials facility across the base. Classified material receiving and loading is documented using hand-written tallies on hardcopy documentation, with are later manually updated into WPS by a Transportation Clerk.

RFID Quality Control (QC) Initiative

The initial scope of passive RFID use at the CFS was intended to be a short-term QC initiative, utilized in conjunction with legacy documentation methods, to gain additional visibility within the transit shed and identify potentially undocumented shipments in SEAVAN containers. The concept was that passive RFID tags would be put on each shipment at receipt. An unmanned portal constantly scanning for EPCs passing between the staging area and the container doorways would read the passive RFID tags. Shipments would then be documented using the JANUS JR2020 scanners at the container doorways. The passive RFID read would be used to trigger an alert to QC personnel if a shipment was seen leaving stow, but no corresponding stuffing transaction appeared within the next hour. This limited QC initiative was funded with enough passive RFID labels for six weeks. After that point, it would be determined if longer-term implementation of the technology was cost efficient. The project was created prior to the release of DoD's policy letter on RFID, and at that time, there was no intent to use RFID as a transaction of record.

Equipment was ordered in October 2003, and programming began at that time. A single workstation was fielded with an Alien Technology, Incorporated (Alien) two-port reader in November 2003. For the period of the next month, shipments arriving via small package carrier were tagged with Alien Class 1 EPC devices. Testing and software modification continued into December 2003.

During this initial testing and programming, results of the passive RFID read tests far exceeded the expected capability of the equipment. Those read rates, combined with a concept of a manned portal that could support a business process capable of achieving 100% accuracy, allowed for an expanded concept for passive RFID utilization at the Ocean Terminal. Taking into account the requirements of the newly released DoD policy on RFID, the scope of the initiative was changed from being a QC check of the legacy documentation process to a replacement for the legacy documentation process.

RFID Pilot

The first formal RFID training for CFS employees was conducted during December 2003 to provide employees a detailed understanding of RFID and how the pilot operation was going to operate. All remaining receiving workstations were outfitted with Alien readers and antennae to be ready for full scale receiving in early January 2004. With the exception of HHG, outsize/overweight, and classified shipments, all shipments received after this fielding in January were tagged with a passive RFID device.

Development of the stuffing workstation and associated business processes began after final fielding of the receiving function, and resolution of all issues in that part of the operation. The first version of the OTMS Stuffing software was available for live testing in late January 2004. A prototype Stuffing portal was designed and constructed to process the various types of shipments that were to be presented; small packages, mixed pallets, and large single pallets.

Figure 3 *First Prototype of the Stuffing Workstation*

The first Stuffing workstation consisted of a computer workstation on a portable cart. Connected to the cart was a small section of gravity (caster) conveyer that connected to a collection bin *(see figure 4)*. Adjacent to the workstation was a 10’ x 10’ arch, constructed from 2” electrical EMT conduit. The portal was equipped with three Alien two-port readers and a total of six circular polarized antennae. Testing for maximum read rates was conducted to determine the maximum height and distance separation for the various antennae. Because the equipment provided no means to cross-link multiple readers to coordinate the signals from all six antennae, antenna placement on the portal needed to be designed to alleviate the possibility of dead zones caused by interference patterns from antennas on different readers. An Alien two-port reader was mounted on each side of the portal with two circular polarized antennae connected to each reader. One of these readers and corresponding set of antennas was connected directly to the workstation cart, the other hung on the conduit arch across from the cart. A horizontal distance of ten feet separated the two sets of antennae in both directions *(see figure 5)*. The antennae were also positioned so as to be facing slightly away from one-another. The third Alien two-port reader and two circular polarized antennae were attached to the conveyer section. These antennae for the conveyer were oriented to be facing away from the antennae in the portal, and were on the top and side of the conveyer. A tethered barcode scanner was also attached to the workstation to allow for scanning of TCNs when the passive RFID could not be read.

Figure 4 ***Gravity Conveyer on Prototype Stuffing Workstation***

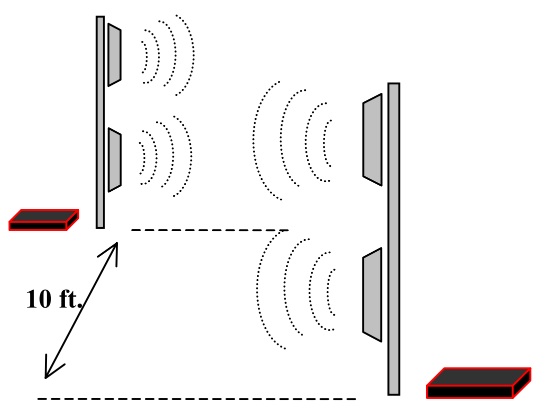

Figure 5 *Horizontal Antennae Offsets*

With demonstrations to senior Department of Defense officials that the project had achieved successful passive RFID read rates exceeding 85% and overall business process effectiveness of 100% manifest accuracy, it was decided to expand the in-house FISC Norfolk pilot to an official Navy initial implementation of passive RFID.

RFID Implementation

Additional funding was received from the Navy AIT Project Office and FISC Norfolk to expand beyond the pilot phase. The plan was to fully implement RFID into the Ocean Terminal stuffing process and utilize passive RFID for updating the transactions of record. Additional purchases included RFID tags, four-port readers and antennae, tri-lock structural portal hardware, handheld scanners, and continued contractor support.

The design of the portal was modified twice during the initial implementation phase. The first redesign occurred when the newer Alien four-port readers were received to replace the initial two-port readers. These readers not only supported an additional two antennae each, but also allowed for a much greater cable length on each antenna. The first concept was to utilize two readers in the portal, for a total of eight antennae. A single reader will coordinate the signal it sends to each of its four antennae in such a way as to avoid any possible interference between antennas, regardless of their relative orientation to one-another. However, new equipment still offered no means of cross-connecting multiple readers to allow similar coordination across both readers and all combined antennae. As a result, despite extensive trial and error testing, it was impossible to find an antenna placement scheme in the tunnel that did not create significant dead zones when more than one reader was active.

Figure 6 ***Antenna height as compared to a double-stacked pallet of drums***

An interim design was developed to have a "high reader" and a "low reader." Each designed to separately capture EPCs from the bottom pallet in a double-stack and the top pallet in a double stack, respectively. The corresponding business process required a pass with the bottom reader on, and then a second pass with the top reader on. The software required the input of the operator to determine which readers needed to be on for a given pass. It was quickly determined that this business process was far too cumbersome to be practical, and plans for multiple readers in a single tunnel were dropped.

Further testing with the new tunnel configuration determined that optimal antenna heights were at 36" and 72" *(see figure 6)*. These heights allowed antennae from a single reader to capture tags from all but the highest placements on a double-stacked pallet, and all but the very lowest placement of tags on a single pallet. Instructing the drivers to raise the height of the forklift tines as they approached the read area could easily solve the problem of missing low tags on a single pallet.

At this time, the concept of a gravity conveyer was dropped from the stuffing workstation. It was determined that it was easier to read small boxes and envelopes in the tunnel with other shipments than it was to offload them onto the conveyer. The original conduit arch was also replaced with a new design, which also used conduit, but created a somewhat more stable platform for the reader and antennae.

The third and final revision of the stuffing workstation, a few months later, addressed two additional issues. First, the conduit arches were flimsy and not consistent with a permanent installation in an industrial environment. Secondly, despite temporary measures to alleviate extraneous reads through the use of portable office partitions, the portal designs using an arch concept precluded the staging of freight within twenty to thirty feet of the antennae, as bounces and reflections of the RF signal often picked up cargo that was not in the intended read area.

To provide the required stability, the conduit was replaced with portable structural beams, designed for use in trade shows. They were lightweight enough to allow the workstation to be moved, if necessary, yet sturdy enough to survive in a working environment *(see figure 7)*.

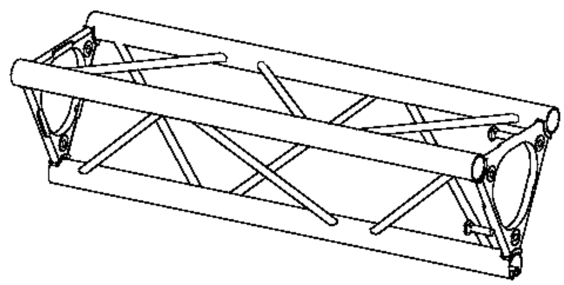

Figure 7 ***Cross section of tri-lock beam used to create the new tunnel***

To eliminate a majority of the extraneous reads, the portal was expanded from an arch to a tunnel. An RF barrier, attached to the tri-lock frame and tied to an electrical ground, was stretched between the legs of the tunnel. This barrier was constructed of 14 gauge ¼” wire mesh. With the exception of areas immediately adjacent to the tunnel entrance and exit, this grounded mesh restricted the RF signal to the confines of the tunnel, and allowed staging of cargo immediately adjacent to the read area.

The workstation was also redesigned to support two side-by-side tunnels with a single operator located in the middle.

Business Process of Scanning Shipments in the RFID Portal

The updated OTMS software now used in the stuffing portal is operated by a ‘checker’ who is able to work with multiple drivers as they load shipments into their assigned SEAVANS. When a driver is assigned to load a specific SEAVAN, they provide a copy of the SEAVAN paperwork to the portal operator, who creates a record in OTMS linking the driver's name to that SEAVAN. The record also includes information from WPS as to consignee and port of debarkation (POD) for the container.

As a driver approaches the tunnel with freight to be loaded into their container, the operator clicks on the appropriate driver name, setting RFID reads in the tunnel to the context of the SEAVAN to which that driver is assigned. The operator's screen displays

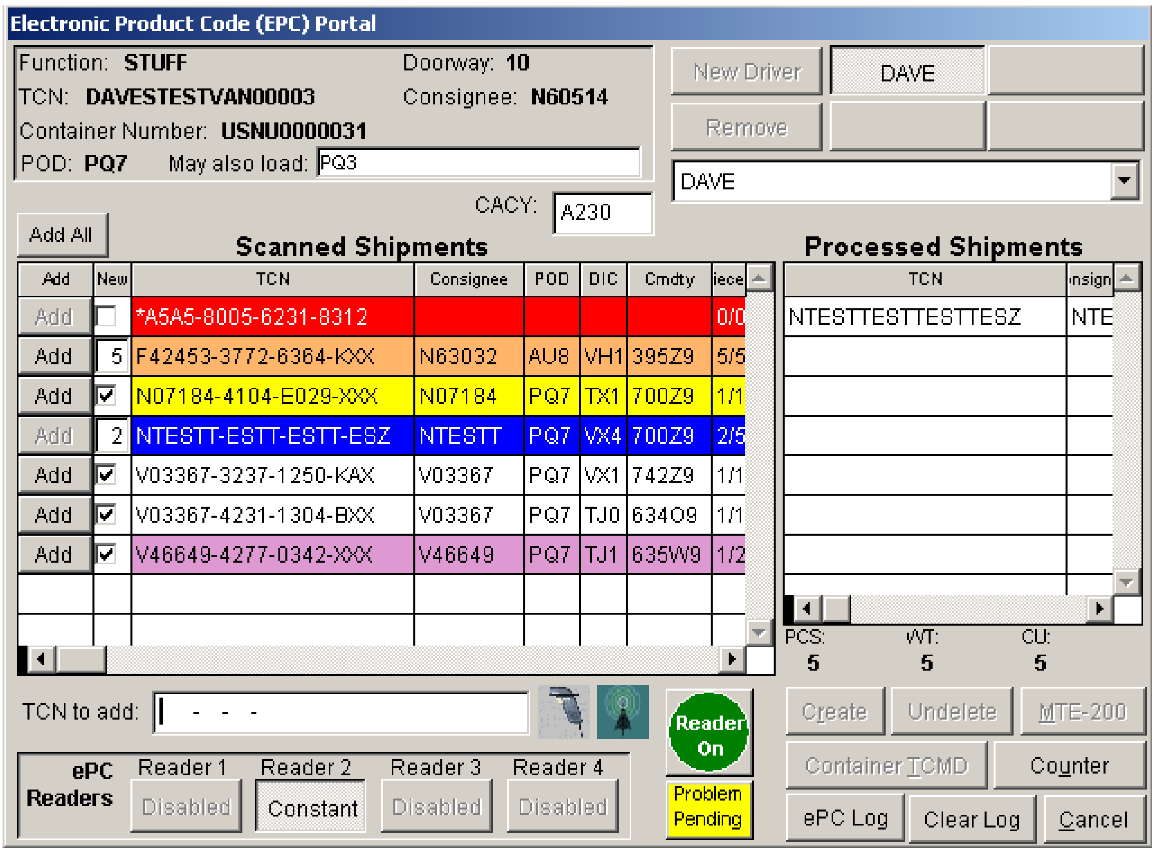

Figure 8 *EPC Portal Operator's Main Screen*

information about that SEAVAN container and any previously-scanned shipments *(see figure 8)*.

The driver is given visual feedback via two computer monitors in the tunnel and traffic light. When the portal is not ready to read EPCs, the monitors display a "Do Not Enter" sign *(see figure 9)*, and the traffic signal is red. To have the tunnel activated, the driver indicates to the operator the number of shipments he/she is about to drive through the tunnel. The

Figure 9 *Tunnel display to driver when tunnel is not ready to scan. In this case, no anticipated number of shipments has been entered yet.*

operator keys this number into OTMS *(see figure 10)*, which displays the number of expected reads on both the operator and driver's monitors *(see figure 11)*, activates the Alien reader, and turns the traffic signal green *(see figure 12)*.

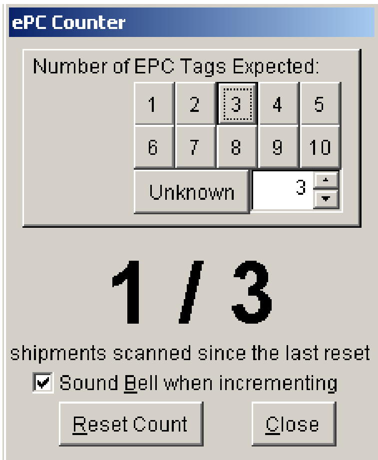

Figure 10 ***Counter on the Portal Operator's Screen***

Upon receiving the green signal, the driver verifies that his/her name and the correct number of shipments are displayed on the monitor in the tunnel, and then drives into the tunnel. As the system detects passive RFID devices, it provides the driver with audio signals and updates the display on the video monitors in the tunnel. At the same time, detailed shipment information corresponding to each EPC is displayed on the operator's screen *(see figure 8)*. This information is color coded to assist the operator in determining if the shipments being scanned are appropriate to be loaded in the active container. *(See figure 15 for a description of these colors and further details about the operator's screen.)*

If the driver gets to the end of the tunnel without the system having read the anticipated number of EPCs, he/she knows from the display in the tunnel to back up and bring the shipments past the antennae a second time, in reverse. Often, the drivers will change the height of the forklift tines for this second pass.

Figure 11 ***Tunnel display to driver when tunnel is ready to scan. Currently 1 of 4 anticipated EPCs have been scanned.***

Figure 12 ***View of tunnel showing green traffic light and one of two monitors that inform driver of status of the read***

When the system has read the anticipated number of EPCs, it will send one of two signals to the driver. If any of the EPCs appear to the system to be inappropriate for the container being loaded, a buzzer sounds, a voice message tells the driver to return to the operator's station, the traffic light displays yellow and red lights, and the computer monitors display a message that there is a problem *(see figure 13)*. The driver and operator then inspect the detailed messages on the operator's screen to determine the shipment or shipments the system is questioning. They then either take the discrepant shipments off the pallet, or override the computer's assertion that there is a problem.

Figure 13 *Tunnel display to driver when all anticipated EPCs have been read, but there is a problem with one or more of the shipments. Driver must see the tunnel operator before leaving the tunnel.*

If, on the other hand, the system reaches the anticipated number of shipments without encountering what it believes to be any suspect shipments, a bell sounds, the traffic signal shows a blue light, and the monitors in the tunnel display a message telling the driver to proceed to the SEAVAN *(see figure 14)*.

Figure 14 *Tunnel display to driver when all anticipated EPCs have been read and there are no problems with the shipments.*

Even when the system has read the anticipated number of RFID devices, the reader remains active for an additional thirty seconds, in the event the driver miscounted and there are more EPCs than anticipated.

Once the driver has cleared the tunnel area and the operator has reviewed the scanned shipments on his/her screen, he/she will press the "Add" button to move the shipments from a "scanned" status to a "processed" status, also updating the appropriate records in WPS (see). At this point, the shipment moves from the left list on the operator's screen to the right list, indicating processing for that shipment is complete.

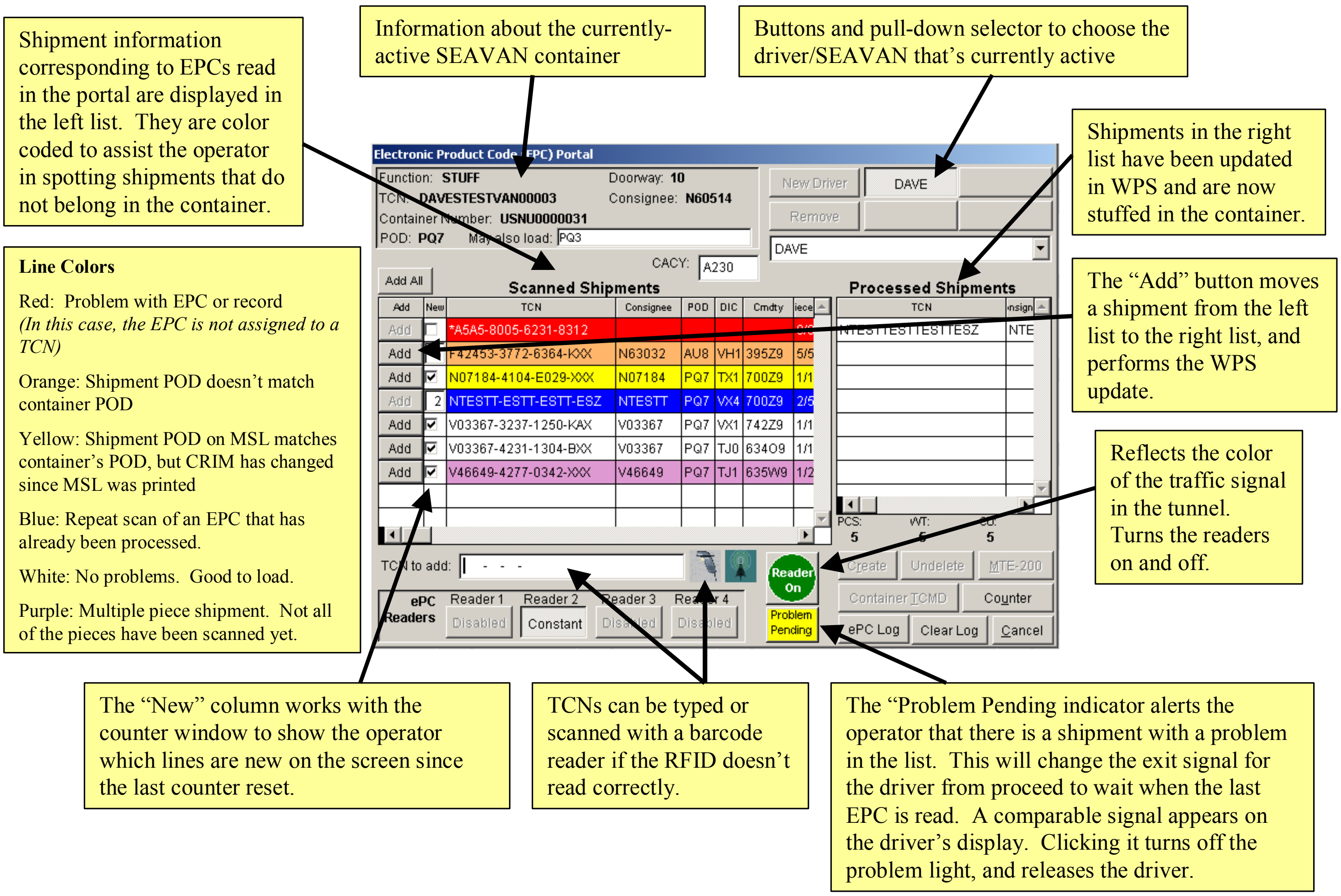

Figure 15 ***EPC Portal Operator's Screen, Features Described***

EPC Process Flow and System Interfaces Diagrams

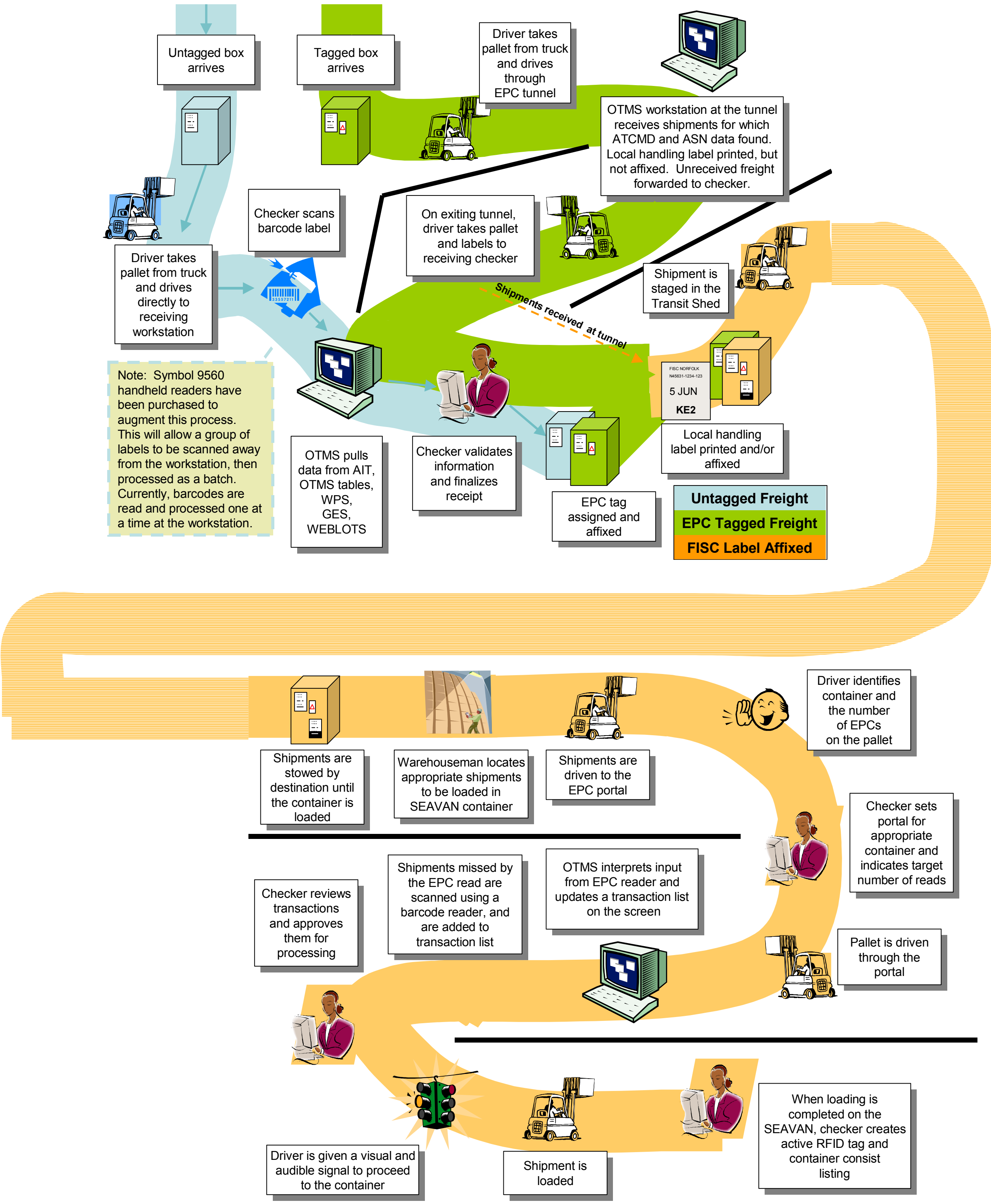

Figure 16 *Graphical process flow of receipt and shipping of freight at the CFS*

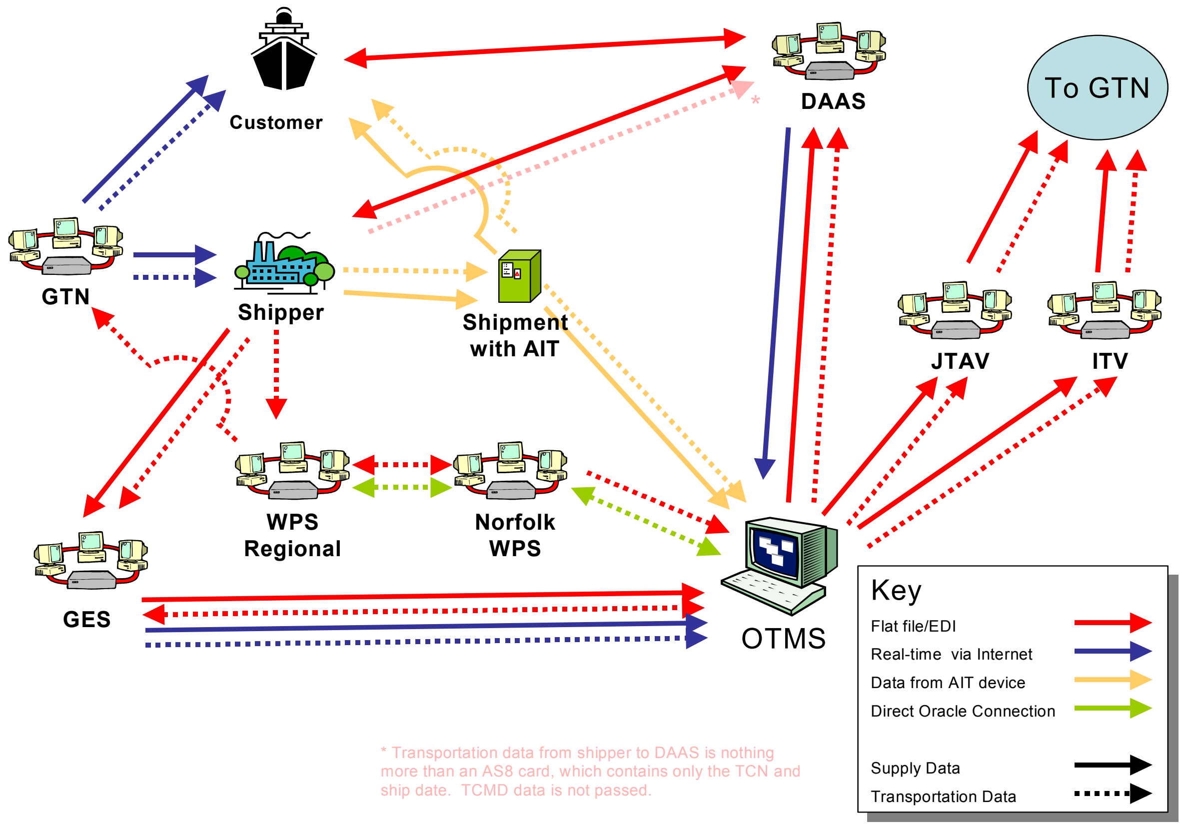

Figure 17 *System Interface Map and Data Flow*

Equipment and Costs

The final components of the receiving workstations and stuffing portal are:

Receiving workstations (6)

- Standard NMCI Workstation (networked)
- Computer Cart
- Alien two-port reader
- 1 Alien circular antenna
- Symbol 9050 Portable Data Collection device with cradle
- Intermec 3400 Label Printer
- USB Hub

Stuffing portal and workstation

- Standard NMCI Workstation (networked)
- 2 Stand-alone legacy workstations
- 4 Legacy computer monitors
- 2 VGA signal splitter/amplifiers
- Computer Cart
- Equipment cabinet
- USB Hub
- Tethered barcode scanner
- 2 Alien 4 port readers
- 8 Alien circular antennae
- Tri-lock portal
- RF Barrier
- Intermec 3400 Label Printer
- 6 Portable Jersey Barriers

The associated costs for the implementation are captured in the chart below.

Standard Receiving Workstation (6 in use)	Qty	Unit Cost	Total Cost
Standard NMCI Computer Workstation w/ monitor, keyboard, mouse, sound card, speakers, and network drop	1	$2,000	$2,000
Computer Cart	1	$400	$400
USB-to-Serial converter to add additional COM port	1	$40	$40
Intermec 1551 tethered barcode scanner (linear / 2D capable)	1	$800	$800
Alien Technology Reader Kit, 915 MHZ, two-port	1	$2,250	$2,250
Antenna, Circular	1	$353	$353
Symbol 9060 Portable Data Collection Unit w/ Base	6	$2,544	$15,265

Intermec 3400 Label Printer	1	$1,194	$1,194
Subtotal			**$22,302**

EPC Portal Workstation (1 in use)	Qty	Unit Cost	Total Cost
Standard NMCI Computer Workstation w/ monitor, keyboard, mouse, sound card, speakers, and network drop	1	$2,000	$2,000
Computer Cart	1	$400	$400
Equipment Cabinet	1	$400	$400
USB Hub	1	$45	$45
USB-to-Serial converter to add additional COM port	5	$40	$200
Intermec 1551 tethered barcode scanner (linear / 2D capable)	1	$800	$800
Alien Technology Reader Kit, 915 MHZ, 4-PORT	2	$1,999	$3,398
Antenna, Circular	8	206	$1,648
Intermec 3400 Label Printer	1	$1,194	$1,194
Non-networked Pentium Workstation *(Used to run forklift driver video displays)*	2	500	$1,000
Video signal splitter *(Used to drive multiple monitors in the tunnel for driver feedback)*	2	$578	$1,156
VGA Monitors	4	$100	$400
Hanging Monitor Stands	4	$49	$196
Tri-lock Display Units *(Structural beams used to build the tunnel)*	1	$8,289	$8,289
RF Barrier (W*alls of the tunnel)*	1	$300	$300
Misc Mounting, Installation, electrical, data cable, etc.	1	$3,000	$3,000
Electric Eye *(Sounds alarm if freight or forklift get too close to side of tunnel)*	8	$74	$592
Driver Signal Lights	2	$150	$300
Subtotal			**$25,318**

EPC Tags	Qty	Unit Cost	Total Cost
Alien Class 1 D Tags	135,000		**$59,300**
Contractor Support			$130,000
In-house development	1 Man-year		$70,000
Grand Totals			**$306,920**

Lessons Learned

During the implementation of RFID at the Ocean Terminal, there were numerous changes and opportunities for improvement to business processes, RFID reading, RFID label placement, training, software, and tag procurement. The continuous refinement of all areas of the implementation resulted in a state-of-the-art RFID logistics process that has made a notable impact on the overall operation at the Ocean Terminal. The most significant impact on the operation has been the elimination of hand scanning with the JANUS JR2020 in the Stuffing area. Listed below are details of the 'Lessons Learned' during the course of the project.

Category	Issue	Lesson Learned
RFID Tagging	Large variety of material handled	*Workers have to be educated as to the proper placement of RFID tags on the material.* There **is not** one universal tag placement for all material.
RFID Tagging	Accountability for all pieces of a TCN	*All pieces of each TCN must be tagged for traceability.* Originally, the concept was that only one piece per TCN would be tagged. However, in the first day, it became apparent that all pieces would have to be tagged for proper accountability.
RFID Tag Orientation	Inconsistent Reading of Tags	*Tag positioning on material: Vertical - Best, Horizontal - Good, Forward facing - Good, Backward facing - Fair, Top of material – Poor.* The proper orientation for the RFID labels when moving through the portal is important for the greatest read rate success with the Circular Polarized Antennae.
RFID Tag Placement	Poor Tag reads	*Proper placement of tags on various types of material is critical to the read success rate.* Personnel who apply the tags must understand basic principals of RF and identify material that may have a detrimental affect on the readability of the RFID tags. Workers must identify areas of boxes where metal or liquids are less likely to touch the sides and apply the labels in these areas. Tags should not be placed on the top of boxes or material. Hanging tags or a foam spacer should be used when tagging metals, liquids, or extremely dense materials. When applying tags to rounded material, the tag should be placed in a parallel position to the package or material (the RFID tag should not be wrapped around material or detuning of the antenna will occur). Metal containers and packages containing liquid present the hardest-to-read shipments. Tags affixed directly to tires also have an extremely low read rate.
Mixed Pallets	Difficulty reading RFID tags on mixed pallets	*When consolidating material for placement on mixed pallets every effort should be made to ensure that all RFID labels are facing outward*. RFID labels must not touch one another or there will be a no read situation. Tags should not be buried in the middle of a pallet, or have an RF-blocking material such as liquid or metal

		blocking line of site to the reader.
Training	Recurring tag placement problems	*RFID training was necessary on a recurring basis (every few weeks) to reinforce proper tagging procedures and pass along new lessons learned as to hard-to-read materials or shipment configurations.* Workers were instructed on the proper placement of RFID tags on material. Problems, mistakes, and new lessons learned were shared with the work force on a regular basis.
RFID Tag Reading	Extraneous Reads	*The antennae were picking up tags outside of our intended scanning area.* Initially, cubicle partitions were constructed on either side of the portal to eliminate the problem. The final version of the portal has a RF barrier material on each side that contains most RF emitted by the antennae. Even with the RF barrier, however, there are still occasional extraneous reads through the entrance and exit of the tunnel.
Portal	Photo Eye Coordination	*Using a photo eye to control the reader will not always work with the portal workflow.* Initial thoughts were to activate the readers when a forklift broke the beam of a photoelectric eye. The reader would remained on for a fixed duration (15 seconds, initially. Later extended to 30 seconds.) The sequencing of this was very difficult, as different drivers would move at different speeds through the portal. The speeds were also affected by the size and nature of the freight. An effort to synchronize a second photoelectric eye with the reader to maintain it in a read state for as long as the forklift remained in the read area were also unsuccessful. Without a large number of sensors in the tunnel, it was impossible to cover the entire area. As the business process that eventually developed acknowledged the presence of a tunnel operator, the auto-sensing initiative was thought to be unnecessary, as there would be an operator to activate and deactivate the reader.
Reader / Antennae	Reader Placement	*The placement of the reader must be in close proximity to the antennae.* The two-port antenna cables were 6 feet in length. The four-port antenna cables were 20 feet in length. Neither of these fixed antenna lengths provided for a great deal of flexibility in reader placement. If additional antenna cable is added, signal strength is derogated in direct proportion to the added cable length. The four-port reader has a setting to decrease signal strength is shorter cable runs are used, however there is no capability to boost the signal beyond the pre-set value which is consistent with 1 watt per antenna at 20' cable length.
Reader / Antennae	Reader Placement	*The reader should be placed in an area with easy access for maintenance personnel.* From time to time, there is a need to access the reader to perform checks or maintenance.

Reader / Antennae	Antenna Placement (two-port)	*When operating two readers directly across from each other, RF interference was created prohibiting optimal read rates.* Use of two-port readers required one reader and two antennae on each side of the portal. To minimize the effect of signals from opposite antennas canceling one-another out, the antennae were staggered in the portal (10 ft. apart in two directions) to allow for the best-read rates. When the four-port reader was obtained, the reader was capable of sequencing the four antennae to eliminate the interference problem. The 10 foot separation was no longer necessary.
Reader / Antennae	Antenna Placement (four-port)	*When operating two readers directly across from each other, RF interference was created prohibiting optimal read rates.* Upon receiving two 4-port readers, testing was conducted to determine if there is an increased read rate by using two readers and 8 antennae in the portal. The use of the two readers and 8 antenna created RF interference and degraded the read rates. In the final configuration, we went back to one reader and four antennae.
Reader / Antennae	Reader settings	*The factory reader settings were very good and little or no changes were required.* Various reader settings were adjusted in an attempt to maximize the read rates. Only one small change to the reader setting was used in the final evaluation. Auto stop timer was increased to 500 milliseconds.
Change Management	Receiving	*We must continuously communicate with all personnel to ensure they understand the larger picture, including the need for change. We also need to listen and react to their concerns*. A small change to the receiving process was instituted to scan a RFID tag, match it to a TCN, and apply it to the material. While this process added only about five seconds to the receiving process, the workers were initially concerned about the additional time necessary to work through the new process. They were shown how those extra five seconds up front were saving much more time in later parts of the overall process. They were also assured that the additional work in their work area was not being counted against them in any productivity reviews.
Portal	Portal Design	*A "Wal-mart" dock door portal design will not work for all applications.* Passive RFID can be used in one of two ways. It can be used as a means of added visibility, or it can be used as a transaction of record. If using the technology as an additional method of visibility, a transaction simply means "this item was seen near this reader at this date and time." To use the technology to perform a transaction of record, though, there has to be context associated with the RFID read. This context can be obtained in several manners. One can be the location of the reader. "If I see a tag in the receiving bay, I will receive that shipment." Another context can be based on directionality. "If I see a tag on the outside of the door, then see it on the inside of the door, I will

		receive the shipment. If I see it on the inside first, then see it on the outside, I will issue the shipment." However, at the FISC Norfolk Ocean Terminal, we wanted a very specific transaction. We wanted the transaction to be, "The shipment left in container ABCU 123456 to consignee N12345 at POD code PQ3." To get to that level on detail, there needed to be two things. First there needed to be a way to assign the context of the specific SEAVAN container to the reader, and there needed to be a way to ensure that only shipments that should be applied to that context were read. The context of the specific SEAVAN is assigned to the reader based on the computer displays in the read area. The insurance that only the shipments to which that context apply will be read comes from the RF barrier that prevents the reader from seeing any shipments other than those physically inside the tunnel. A exact portal design was customized for the Ocean Terminal application based on factors such as proximity of LAN drops, proximity of stowed tagged material in the immediate area, likelihood of forklifts not in the tunnel traveling near the tunnel with tagged shipments, location of electrical power, and the operational flow of material through the facility.
Reader / Antennae	Reader Connectivity	*Network compliance and security must be considered when making reader connectivity decisions.* The readers are connected via serial cable to the workstation PCs. NMCI rules precluded attaching readers as a network device in the timeframe available to the project. Fortunately, serial cable lengths for the specific installation did not exceed a length at which reliable communications could be maintained. Alien readers have a fixed baud rate and no error correction capability with the serial port.
Reader / Antennae	Overhead Antennae	*Overhead antennae did not significantly increase read rates.* Tests were conducted with two antennae located at the top of the portal facing down. The concern was that we were missing tags located high on pallets, or tags sitting on top of the pallet facing up. Because of the necessary height of the portal, however, the top antennae were too far from the freight to be effective.
RFID Tags	Poor Tags	*The quality of tags received must be monitored.* The Ocean Terminal is using preprogrammed tags. A small number of the tags received from the vendor did not read. Some of these tags could be used after being reprogrammed. A very small number could not be reprogrammed, either.

RFID Tags	Duplicate Tags	*The quality of tags received must be monitored.* Tags were received with duplicate EPC numbers. Approximately 100 tags were identified as having duplicated identification numbers. The OTMS software would not allow the duplicate numbers to be reused at the Receiving workstation. The tags were later identified as duplicate tags obtained from the manufacturer.
RFID Tags	Tag Procurement	*Manage on hand tag stock to ensure sufficient quantities are available.* The tags used at the Ocean Terminal are not on a current GSA Schedule or DoD-wide contract. The procurement time and process for obtaining additional tags required extensive lead-time. In one instance, the contracting of tags required 8 weeks. On a few occasions, the Ocean Terminal exhausted all supplies of tags, thus discontinuing the application of tags on material.
Business Process	Operational Redundancy	*All RFID-enabled processes must have the ability to fall back to other methods of data capture.* When RFID tags are damaged in the warehouse or do not read for other reasons, there must be processes in place to continue the movement of material in the operation. The Ocean Terminal process allows the user to scan barcodes on the Local Freight Tracking Tag or the MSL. The operator may also key in the TCN and piece number.
Business Process	Testing Procedures	*Tighter controls with the shipments tested will allow for reconciliation.* When conducting initial container stuffing tests, shipments were loaded into the SEAVANS immediately after being scanned through the portal. This made later reconciliation of the manifests impossible. It was determined that freight would have to be held without being loaded until all analysis had been finished on the manifest.
Business Process	Testing Procedures	*Tighter controls with the shipments tested will allow for reconciliation.* When conducting initial container stuffing tests, there were occasions when it wasn't clear if freight got loaded into a container without passing through the portal, or if it had been through the portal and had been missed by the process. Tighter controls placed on the business process and testing to ensure no shipments went right from stow to container without passing through the portal.
Software	Customization	*Software customization will enhance the process flow.* While the beginning process flow concept was detailed enough for the Ocean Terminal to operate effectively, the detailed customization of the software enhanced to overall operability of the project. The visual monitor readouts and sound effects assist to increase the accuracy of shipments scanned through the portal.

System Changes	Testing	*When making hardware or software changes, the new process needs to be compared to a known benchmark to determine how it is performing.* In September 2004, it was determined that the OTMS software had a bug that was introduced in a software update more than a month before. The bug was causing the reader to be momentarily reset after each EPC was read and interpreted by the system. This caused the software to "miss" reports by the reader of a certain percentage of the passive RFID tags that were actually being read. Because the success of reading tags with the OTMS software had not be benchmarked against a known software package, the derogation of performance the software bug was causing went unnoticed for a considerable length of time. The existence of the problem was only verified when the same freight was read using the Alien Technology demo software and by OTMS. When the demo software consistently read more tags than the OTMS routines, programmers researched the cause and found the bug.
Funding	AIT Funding	*Communication between Navy AIT Project Office and funded projects required prior to preparing funding documents.* Funds were initially provided from the Navy AIT Project Office under a single MIPR. However, it was not possible to find a single source for all material and services authorized for funding by Navy AIT Steering Group. FISC Contracting was not able to process multiple procurements to different vendors under the single MIPR. Multiple corrections and additional financial transactions were required to finalize the purchases. When applying for the Navy AIT Steering Group funds, it was not clear on the application that amounts submitted would be used for an actual funding document. We believed they were estimates for planning purposes only.

NMCI Issues

Several of the challenges faced during the course of the project were hurdles caused by the Navy business rules associated with the Navy-Marine Corps Intranet (NMCI). These rules made prototype and development initiatives a challenge.

The first challenge was the restriction from placing passive RFID readers on the NMCI network itself using their Ethernet capabilities. As the readers were not an approved NMCI network device, and as there was no CLIN in the NMCI contract to support them as an ordered service, there was no way to hang them off the existing Ethernet network. In addition, there are no provisions for placing a second, non-NMCI network interface card (NIC) into an NMCI workstation, so a new legacy network (machinery network) dedicated to the readers was also not an option.

Fortunately, the readers purchased for the pilot had full operational functionality available through the RS-232 serial console port. As this console port communicates with the workstation using standard communications protocols, and did not require a device-specific driver or dynamic link library (DLL) file, it could be attached to the workstation. As multiple readers and serial devices were attached to the workstation, though, it was necessary to obtain NMCI-approved USB hubs and multiple USB-to-serial converters.

An additional NMCI challenge was encountered when building the portal. As the portal was being designed to document stuffing operations, the logical location in the facility for the portal was between the staging area and the stuffing doorways. However, no existing NMCI network drops existed in that location. Because the prospects of getting a new NMCI network drop installed were negligible (other NMCI network drop requests in the same warehouse have been pending for nearly two years), the decision was made to locate the portal near the receiving doors, instead, where there was an existing workstation.

Another challenge revolved around the need for multiple monitors to be driven from a single workstation, each with a unique output. While the technology exists to place multiple monitors on a single computer and independently manipulate the display on each, there was no provision for such equipment in the NMCI contract. So, in order to have a unique display for the EPC portal operator and drivers in each of two tunnels, two legacy computers are utilized as “display devices.” These legacy computers are connected to the NMCI workstation via a serial device, over which they receive signals as to which message should be displayed in their respective tunnel. An application runs on these workstations to receive and interpret the signals from the OTMS software on the NMCI workstation. While this method was certainly more cumbersome than having additional monitor cards added to the NMCI workstation, it is fully functional.

The final area of difficulty in fielding the pilot in the NMCI environment had to deal with the Symbol 9505 Portable Data Collection Devices (PDC) that will be used on the receiving workstations to scan MSLs and MROs. While these devices were purchased with a built in antenna to communicate with OTMS in real-time, there are no provisions for attaching an RF-connected device to the NMCI network, even despite their compliance with Federal Information Processing Standards (FIPS) Publication 140-1. As a result, the plan is to use these RF-enabled devices in a docking station batch mode. It is hoped that the Microsoft Active Sync software required to interface with the docking stations, which has been Functional Area Managers (FAMS) approved in the Department of the Navy (DON) Application Database Management System (DADMS) for other DON sites, will likewise be approved for FISC Norfolk use.

Return On Investment

While a financial return on investment (ROI) has not be realized at this time, there has been a notable improvement in the operational efficiency of the overall export CFS process, which has allowed for a reallocation of manpower within the organization. In the legacy process, a dedicated checker was required for each SEAVAN being loaded. In the EPC-enabled stuffing process, a single checker operating the EPC portal serves all containers being loaded. During a normal workday, three to four containers may be working at a time. During peak loading and when the operation is supplemented with Naval Reservists or Stevedores from the Division's Ship Operations Branch, as many as ten to twelve containers may be loading simultaneous. This single checker at the EPC portal has been able to keep up with those peak demands. So, depending on the variable number of SEAVANs being loaded, as many as twelve additional personnel could conceptually be assigned as additional drivers, or to work in other functions within the operation.

The elimination of hand scanning with JANUS JR2020 PDCs has also resulted in overall faster processing of the material. In a vast majority of the cases, the checker no longer has to manually scan barcodes. There is no longer a need to wait for a sluggish RF response from the network access point after each TCN, nor is there the challenge of keeping track of which freight in the often-congested loading area has been scanned and which freight has not.

It is also believed that there has been a vast improvement in inventory accuracy for the containers that have been processed via RFID vice the JANUS JR2020 barcode scanning. A small sample of containers that were tested for timeliness and accuracy, comparing the two processes, is provided in the section entitled Metrics. Additional details with regard to manifest accuracy are also provided in that section.

Certainly, the efficiencies gained will not reconcile the $306,920.00 in startup costs in the near-term. And, at 37¢ per piece, or an average of 93¢ per shipment, a financial return on investment will be impossible to achieve in a stovepipe application at the FISC Norfolk CFS. However, if these ongoing costs of 93¢ per shipment can be leveraged over many DoD sites achieving similar efficiencies, there is a potential for a financial return. Those potential savings, however, are outside the scope of this study, and will be reviewed in detail by Business Case Analysis (BCA) studies currently being conducted by others.

Metrics

The FISC Norfolk pilot was not designed with the goal of providing financial Return on Investment (ROI) justifications for the use of passive RFID. As there was a signed DoD policy mandating the use of passive RFID, the premise was that DoD already had compelling financial and/or strategic justification upon which the policy was based. The goal of the pilot was therefore not to justify a ROI, but rather to prove that the technology could be effectively used as a transaction of record in a business process that achieved an acceptable level of accuracy. Along those lines, metrics captured were oriented toward the technology and business process, and not aligned to detailed analysis of financial or manpower impacts.

Some anecdotal conclusions can be drawn in the area of financial and manpower impacts, however it is difficult to develop hard numbers to prove the assertions. The Material Handler and Stevedore workforce at the FISC Norfolk Ocean Terminal Division is structured in a Labor Pool or Union Hall concept. Employees are not assigned to a specific position description for CFS Receiving or CFS Stuffing, but are instead assigned to a general position description for the entire operation. Their assignments are tracked in the Standard Labor Data Collection & Distribution Application (SLDCADA) by Cost Center and Job Order Number, but unfortunately those breakdowns are not by function; they are by customer, instead. So, while it is possible to reconstruct the number of man-hours spent on CFS operations for any given day, it is not possible to reconstruct the number of man-hours spent on receiving versus stuffing, or driving versus checking. Definitive man-hour savings figures as a result of passive RFID implementation would be contingent on such figures being available.

Extensive efficiency results as to manifest accuracy are also hard to track down. For a small sample of containers, the EPC-enabled process was directly compared to the legacy process for the same shipments. Details of this sampling are provided later in this section. However, the methodology necessary to make these detailed comparisons was manpower intensive, extremely disruptive to operations, subjected the shipments to increased handling and therefore an increased potential for damages, and also caused delays in getting the test shipments called back to the carrier. The level of effort required to continue the testing was considered to be having a negative impact on the division's ability to keep up with the demands of meeting processing goals to keep important sustainment freight moving to the war fighters. When it was determined that the results of the small sample of SEAVANs already tested were following a clear trend, a command decision was made to discontinue the side-by-side comparisons.

The methodology of comparing the legacy documentation method with the EPC-enabled processes was to allow a stuffing team to completely process a SEAVAN with the legacy documentation procedures. To ensure a blind sampling, warehousemen were not informed as to which SEAVANs would be used for the test until after their processing had been completed. When container documentation was finished, a container manifest was printed, based on the information updated in WPS by the JANUS JR2020. The WPS records were then manually regressed one at a time back to an on-hand breakbulk status, and the freight was returned to the staging area. The container was then entered into the OTMS EPC Portal software and the SEAVAN was stuffed a second time using the passive RFID-enabled process.

At the completion of the passive RFID stuffing process, a second container manifest was printed showing the results of the EPC documentation process. These two container manifests were then compared to one-another. If there were differences, the actual freight was checked to determine which of the processes was correct. An approximation of the time required to complete both documentation methods, adjusted for breaks and the number of personnel involved, was also captured.

The results of the small sample of containers for which this comparison were performed is as follows:

	Date	Destination	Legacy Stuffing Time	EPC Stuffing Time	Stuffing Variance	Legacy Count	EPC Count	Actual Count	Count Variance	Comments
1	28-May-04	PQ7-Jebel Ali	4:25	2:30	1:55	139	142	142	3	3 pieces not scanned. Slow system response time during legacy scan.
2	19-May-04	JG1	0:10	0:30	(00:20)	62	64	64	2	Checker split shipment by mistake
3	14-May-04	PQ7-Jebel Ali	0:20	0:20	0	47	49	49	2	EPC process identified 18 shipments for Navy consignees that had moved.
4	29-Apr-04	KJ2	1:00	0:35	0:25	79	79	79	0	Identical counts.
5	28-Apr-04	CK1	0:24	0:30	0:06	84	91	91	7	7 pieces missed during legacy process
6	23-Apr-04	LD9	0:15	0:10	0:05	31	33	33	2	2 pieces missed during legacy process on pallet of 18 (captured by the EPC scan)
7	22-Apr-04	PB1	0:11	0:08	0:03	20	20	20	0	Did not read EPCs on steel brake casings.
8	22-Apr-04	PB1	0:20	0:17	0:03	18	18	18	0	3 EPCs on metal drums did not read.
9	21-Apr-04	JG1	0:23	0:11	0:12	12	12	12	0	2 EPCs on metal did not read
10	21-Apr-04	HA8	1:40	0:42	0:58	32	31	32	-1	1 Piece short on EPC manifest. Belief is that the piece was not passed through the portal.
	Totals		**9:08**	**5:43**	**3:27**	**385**	**397**	**398**	**12**	
	Averages		**0:54**	**0:34**	**0:21**	**52.4**	**53.9**	**54**	**1.5**	

Other indicators could be used to determine the accuracy of the Ocean Terminal's stuffing documentation performance. For example, the procedures detailed in DoD Publication 4500.32-R, the Defense Transportation Regulation (DTR) for reporting overages, shortages, and damages in a shipment, either through a Transportation Discrepancy Report (TDR) or Cargo Outturn Report Message (CORM) would give FISC Norfolk an excellent understanding of the number of shipments that arrive at a consignee location as undocumented freight. This could then be directly correlated to the success or failure rate of the EPC-enabled process. Unfortunately, container consignees do not routinely, if ever, prepare these reports. In an additional effort to obtain feedback from container consignees, the FISC Norfolk Ocean Terminal also places a customer satisfaction survey inside each SEAVAN loaded. Very few of these surveys have been returned, and none since the start of the EPC-enabled processes. Short of sending analysts to these consignee locations, or specifically eliciting the support of the consignee to gather detailed over, short, and damage feedback, there is no clear method to capture actual effectiveness, other than the intrusive methodology detailed above.

One of the areas that can be checked is the number of shipments that appear on the CFS on-hand inventory as aged shipments. When these shipments reach a certain age, personnel from the division's Customer Service Unit perform a warehouse search for the shipment. If it is still on hand, they initiate expediting procedures to move the shipment. If they cannot find it in on the floor, however, they flag it in WPS as a potentially lost shipment. The number of these flagged shipments can be used as an indicator to the effectiveness of the entire operation; however, they cannot be specifically linked in a one-to-one relationship to the success of the EPC-enabled stuffing process. Shipments that are diverted to CONUS delivery, shipments that are diverted to OPLIFT on an MSC or combatant ship, and shipments that are picked up by the customer or their representative are not documented through the EPC process. Yet, these shipments will represent a certain percentage of the shipments that are flagged as potentially lost.

It is also difficult to determine the time period at which these flagged shipments should be studied. While the EPC portal has been the principal method of documentation for many months, it has not been the exclusive method until more recently. During portal down times when the portal hardware or software was being updated or when one of the few trained portal operators was unavailable, the warehouse reverted to the JANUS JR2020 scanning process. It would be impossible to attribute current lost shipments to one process or the other.

That said, the percentage of shipments flagged as potentially lost dropped from 2.5% in the first half of Fiscal year 2004 to 1.8% in the second half of the Fiscal year. The rate in Fiscal year 2003, before the beginning of the passive RFID pilot, was 4.0%.

The Defense Logistics Agency (DLA) Office of Research and Resource Analysis (DORRA) conducted a three-day time-motion study of the current EPC-enabled processes at the FISC Norfolk Ocean Terminal in mid-October 2004. Using models they believe can reconstruct the JANUS JR2020 processes, and models they create using the data collected in their time-motion analysis, they hope to provide some additional insight into the comparison between the effectiveness and efficiency of the two processes. When available, these findings will be published as an annex to this document.

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